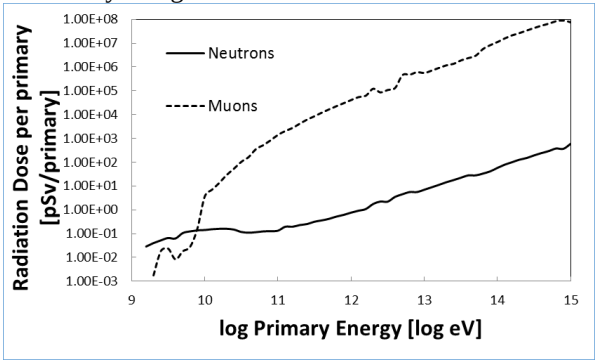
A LINK BETWEEN SOLAR EVENTS AND CONGENITAL MALFORMATIONS: IS IONIZING RADIATION ENOUGH TO EXPLAIN IT? A. C. Overholt[1], A. L. Melott2 and D. Atri[3], [1] Department of Science and Mathematics, MidAmerica Nazarene University, 2030 East College Way, Olathe, Kansas 66062, acoverholt@mnu.edu, [2] Department of Physics and Astronomy, University of Kansas, Lawrence, Kansas 66045, melott@ku.edu, [3] Blue Marble Space Institute of Science, 1200 Westlake Ave N Suite 1006, Seattle, Washington 98109, atri.dimitra@gmail.com

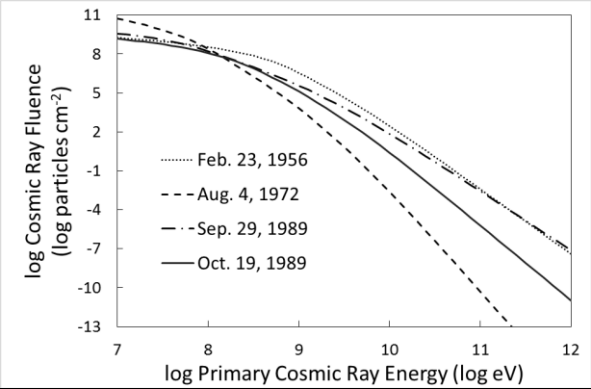
Introduction: Cosmic rays are known to cause biological effects directly and through ionizing radiation produced by their secondaries. These effects have been detected in airline crews and other specific cases where members of the population are exposed to above average secondary fluxes. Recent work has found a correlation between solar proton events (SPEs) and congenital malformations. These correlations have been seen both during the SPEs of October 1989 [1], as well as in the long term periodicity of galactic cosmic rays (GCRs) modulated by the solar cycle stretching back to the 19th century [2].

Ground Level Secondary Radiation. Ground level radiation varies greatly with primary spectrum. Neutrons dominate secondary fluence at energies less than 1 GeV due to their low production energy threshold. Muons have a much higher production threshold, greatly diminishing their contribution at the usual solar energy ranges. We use the lookup tables of Overholt et al. [3] and Atri and Melott [4] to find the neutron and muon fluence at ground level due to primaries of varying energies.

Ground Level Radiation Dose. Neutron radiation dose was found using the work of Alberts et al. [5]. Muon radiation dose was found by calculating the energy loss of high energy muons traveling through matter. The figure below displays the results of these calculations, showing the radiation dose of neutron and muon radiation at ground level due to different primary cosmic ray energies.



Simulation of Historic Events. We now use the results of computational simulations ([3] and [4]) to approximate the ionizing radiation from SPEs which have shown correlation with congenital malformations. Included in this is the modeling of large SPEs measured during the 20th century as well as an event in the 8th century characterized by an increase in ^{14}C at that time. The spectra of these events can be found in the figure below, along with the table showing the results of our calculations.



Event Date	Neutron Dose (μSv)	Muon Dose (μSv)	Total Dose (μSv)
February 23, 1956	0.043	0.007	0.050
August 4, 1972	0.000022	0.0000010	0.000023
September 29, 1989	0.0057	0.0016	0.0073
October 19, 1989	0.0061	0.0020	0.0081
October 22, 1989	0.000074	0.0000043	0.000078
October 24, 1989	0.0017	0.00019	0.0019
773-776 AD	14	2.2	16

Conclusion. We find that the amounts of ionizing radiation produced by these events are insufficient to produce congenital malformations under the current paradigm regarding muon ionizing radiation. We find that this likely means our assumptions about muon ionizing radiation are false. We believe further work is needed to determine the correct ionizing radiation contribution of cosmogenic muons. We suggest that more extensive measurements of muon radiation effects may show a larger contribution to ionizing radiation dose than currently assumed.

References:

[1] Belisheva, N.K. et al. (2012) *Astrophys. Space Sci. Trans.*, 8, 7-17. [2] Juckett, D.A. (2009) *Int. J. Biometerol.*, 53, 487-499. [3] Overholt, A.C. et al. (2013) *JGR: Space Physics*, 118(6), 2765-2770. [4] Atri, D. and A.L. Melott (2011) Rad. Physics & Chem., 80(6), 701 [5] Alberts, W.G. et. al. (2001) *J. of the ICRU*, 1(3).